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# Antenna Considerations for Emerging Implanted Biosensor and Intra-Body Network Applications

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## I. INTRODUCTION

The emerging roadmap for active medical implant devices includes two distinct types of particularly challenging applications that will require the introduction of new antenna and communication technologies. On one hand, there is continued demand for the miniaturization of wireless implants. The quest for more compact solutions is generally application specific, for example, the miniaturization of a swallowable lab-on-a-chip systems that can detect cancer bio-signatures in the gut and relay an instant result to the user's mobile phone. In this case micro mechanical techniques can be integrated with antenna design to create a practical solution in an appropriate form-factor, especially considering that other limiting factors such as battery requirements are more relaxed due to the short lifetime required of the sensor. Therefore, there remains a need for generalized, application agnostic, advances in implant antenna design. On the other hand, there is the emergence of interest in intra-body networks (IBNs) where two or more implanted devices co-operate for clinical advantage. While miniaturization is also a factor in this case, the most challenging aspect of this problem is that both antennas in an intra-body link suffer from severe losses due to the proximity of body tissues and the path-loss is severe due to the relatively high attenuation constants involved. The "both-ends" drawback for IBN links means that any advance in antenna efficiency will be doubly advantageous in these applications. Therefore, the work to be presented will contribute to the conversation around implant antenna solutions by focusing on our most recent work and ideas relating to two fields of interest – minimally invasive implanted biosensors and intra-body networks as detailed below.

## II. MINIMALLY INVASIVE IMPLANTED BIOSENSORS FOR EVERYONE

Minimally invasive implanted medical devices have the potential to transform medical outcomes by enabling the monitoring of patients not only within hospitals but within the community. Typically, body implanted devices are required to operate in positions that are inaccessible or hard to reach, where wires are impossible, unfeasible, prone to infection or less cost-effective. However, radio propagation conditions within the body are particularly complex due to heterogeneous anatomical structures and a wide range of electrical properties for tissues which also presents difficulties in terms of potential antennas detuning, depending on their field coupling characteristics. All of this is compounded by the variability introduced by the dynamic nature of the human body, where even when at rest there will be small movements of organs such as lungs, heart and stomach, and changes in the relative position of tissue interfaces and structures. Medical applications utilizing differing locations within the body therefore present varying requirements for antenna packaging, polarization alignments or usable frequencies. Minimal form factors are essential in reducing the impact of, and to enhance recovery from, surgical procedures to install or remove devices. Design approaches should take account of more than simplistic localized influences but at the same time, avoid adverse impact to patient comfort or mobility. These vary effects are considerably more challenging when we try to consider implant design, not just for an individual, but, for the human population.

## III. INTRA-BODY NETWORKS

Future IBNs require faster and more responsive implants that will rely on wireless communication links and a combination of telemetric biosensors, microprocessors and actuators or simulators where the action of one implant depends on the data received from one or more sensors. It is important to investigate the principles behind such implant antenna to implant antenna cases before developing solutions that are specifically tailored to a single application. The aim of generalized consideration is to develop broader insights and principles that will encompass all implant to implant channels. In some cases, this channel is short and the implants are relatively close to each other such as a cochlear device or in an optical prosthesis ("bionic eye") where the sensory device is within centimeters of the main implant. While in other cases the channel is longer and the signal may need to traverse many tissue interfaces. For instance patients whom may have suffered from a stroke, spinal injury or chronic arthritis, their muscles become very atrophic and lose the ability to respond and may require voltage stimulation to restore contraction or relaxation. The use of an IBN may allow an implant placed in the spinal cord to communicate with the damaged muscle and trigger movement. Similarly, an IBN can also be used in closed loop systems to replace the pancreas and control the blood glucose level. Another application is the control of the urinary bladder to initiate urination. There is a wide range of potential applications which makes the study and understanding of IBNs, timely and vital to the healthcare industry.